

“When the Hurly-Burly’s Done”

Myth and Reality About Transmission Infrastructure

George C. Loehr
gloehr@eLucem.com

Power Engineers Supporting Truth (PEST)

Energy 2004
August 9, 2004 – Rochester, NY

When the Hurly-Burly's Done

The ideas expressed in this talk are my own, and do not necessarily represent those of my employers or clients, past or present

When the Laws of Economics and
the Laws of Physics Collide ...
Physics Always Wins!

NO ECONOMISTS WERE KILLED OR INJURED IN THE
MAKING OF THIS PRESENTATION

Myths of Shakespeare's Macbeth

The witches and the apparition foretell:

- Macbeth will not be killed “by man born of woman”
- Macbeth will not be defeated “till Burnam Wood to Dunsinane shall come”

The same thing's happening today!

History of the World – Part 1

c13,700,000,000 BC

CREATION – BIG BANG

1879 Thomas Edison invents light bulb

1882 Edison invents electric company

Late 1800s Westinghouse – “Battle of the Currents”
Age of Diversity – AC, DC, freq’s & volt’s.

1900 - 1965 Age of interconnections, mergers, acquis’s.

1965 Great Northeast Blackout

1965 - 1996 Age of Reliability – Cooperation & Coord.

History of the World – Part 2

1996	FERC Orders 888 & 889
2000	FERC Order 2000
Early naughts	FERC “big RTO” proposals
2003	August 14 Blackout
2003, 4, 5 -- ?	Energy Bill (?)
2004 > ????	Age of Uncertainty -- Where No Electron Has Gone Before – Competition & Confidentiality

I say we got trouble ... Right here in River City

- Blackouts, terrorism, deregulation, Enron
- New financial, organizational models
- Price – cost in dollars, management, regulation, preparedness
- Dependence on coal, increased use of gas
- Renewables? Nuclear? Energy Bill?
New regulations?
- Reliability and other standards

Electric Energy Production

(million MWH)

Energy Source	Utilities	Non Utilities	Total	%
Coal	1,696.6	271.1	1,967.7	51.8
Petroleum	72.2	36.6	108.8	2.9
Gas	290.7	321.7	612.4	16.1
Nuclear	705.4	48.5	753.9	19.8
Hydroelectric	248.2	24.9	273.1	7.2
Geothermal	0.2	14.0	14.2	0.4
Other	<u>2.1</u>	<u>67.8</u>	<u>69.9</u>	<u>1.8</u>
TOTAL	3,015	785	3,800	100

We're Being Told ...

- Our transmission infrastructure is straining because of heavy transfers brought about by deregulation.
- We have an antiquated, “Third World” grid.
- We need to invest \$100 billion to make it reliable.
- We need to have national, mandatory, uniform standards to be reliable.

Common Element:

It's all about “the Grid” – the bulk power transmission system.

The grid connects the sources of electric energy (generators) with its consumers (light bulbs, air conditioners, refrigerators, computers).

There could be no “deregulation,” no “marketing” – and no *service* – without it.

What *is* a “Grid”?

Battle of the Currents (late 1800s)
DC (Edison) vs. AC (Westinghouse)

- The concept of *economy exchanges*
- The concept of *load diversity*
- The concept of *emergency assistance*
- The concept of *sharing reserves*
- The concept of **INTERCONNECTION**

Albert Einstein

“Everything should be made as simple as possible – but not simpler.”

Grid = “Synchronous Interconnection”

- System or group of systems all of which are connected together with AC lines. Anything that happens anywhere is felt everywhere else. Sometimes called being “in synchronism” – whence the expression, “in synch.”
(Are you listening, Jason Timberlake?)
- An “interconnection” is a **single large machine**.
- Sort of like “**The Borg**” (but no “Seven of Nine”).

Loehr's Second Loehr

POWER FLOWS IN AN INTERCONNECTION VIA ALL PATHS INVERSELY PROPORTIONAL TO IMPEDANCE

Lower the impedance of a path, higher the flow

Higher the impedance of a path, lower the flow

All lines affected by every transaction or
contingency

**Effect of a transaction over one portion of the
interconnection on other portions often
called “Parallel Path Flow” (aka “Loop Flow”)**

Power Swing Equation

$$P_{12} = \frac{E_1 E_2 \sin \delta_{12}}{X_{12}}$$

Guy Consolmagno, SJ

(Contemporary astronomer)

“You never really understand
Physics,
you just get used to it.”

Questions?

Four “Interconnections” (“Grids”) in North America

Synchronous interconnection: a single large machine. Everything's connected with AC. What happens *here* affects *there*.

- Eastern Interconnection 560,000 MW
- Western Interconnection 130,000 MW
- ERCOT (Texas) 60,000 MW
- Hydro-Quebec 30,000 MW

Power Pools, ISOs & RTOs

Traditional Power Pools

- Single control area, centralized dispatch, transmission monitoring
- PJM, New York Power Pool, New England Power Pool

ISOs & RTOs – FERC Commandment 2000

- Thou shall open thy transmission system to all comers on a fair and non-discriminatory basis
- Thou shall form independent associations to manage thy the transmission system
- And they shall be called ISOs (or RTOs)

Myths About the Grid

1. “Third World Grid” (Gov. Richardson).
2. It’s not about “deregulation.”
3. More transmission = greater reliability.
4. Need standards that are
national/mandatory/uniform.
5. Replace today’s “dumb” grid with a
“smart” grid (like the internet).
6. Markets will take care of everything.

1. “Third World Grid”

- If it *were* a “Third World Grid,” the 2003 blackout would never have happened.
- There wouldn’t have been a 560,000 MW grid in the first place.
- **“This was a First World Blackout”**
(*Slate* magazine).
- Raises the question: are present grids too large?

2. Not About Deregulation

- More players, separation of generation from transmission – lead to increased complication, more rules & regulations.
- “Cognitive Dissonance.”
- Culture shift – coord./coop. to competition.
- Physics forced into econometric models.
- Deregulation ... *isn't* !!

3. More Transmission = Greater Reliability

It's important to make distinctions!

- **More transmission = greater transfer capability, ergo greater commercial capacity.**
- ***Tougher, more stringent reliability criteria / standards = greater reliability.***

Should the taxpayers spend \$100 billion so the generators and marketers can make money?

Or, how much should we subsidize future Enrons?

More Transmission Might Make the System *Less* Reliable

- Adding transmission reduces the transfer impedances of the grid.
- i.e., the system is geoelectrically smaller.
- New York is closer to Atlanta, Chicago etc.
- Thus any given disturbance will adversely affect a larger area.
- '03 blackout covered a much larger area than '65 blackout. The next one ...?

**Reliability is a function of the
standards or criteria used,
not the amount of wire in the
air.**

4. National/Mandatory/Uniform Stds.

- Need national standards – but as a floor.
- Already mandatory some places (NPCC, MAAC, SERC, parts of WECC).
- Uniform standards: NY vs. Albuquerque.
- Must have more stringent standards in certain areas.
- These must not be subject to NERC.
- But ... NERC standards now being made less stringent.

Less Stringent Standards?!

<u>NERC Requirement</u>	<u>Old</u>	<u>New</u>
Reserves on	10 min.	15 min.
Reserves refreshed	30 min.	105 min.
Transm. transfer limits (Std. 600)	single cont., multiple element	single element only <i>(ballot soon)</i>
Transm. flows w/in limits >cont. (Std. 200)	30 min.	No min. req'ment. <i>(lost in recent ballot)</i>
Floor or Ceiling	NERC = minimum	NERC = absolute
<i>(DOE Blackout Report and FERC statement support "floor")</i>		

5. “Smart” Grid

Myth: Today’s “dumb” electric grid must be transformed into a smart, self-healing, digital, *internet-like* grid.

Reality: “Like Microsoft software for cars – what happens when you’re going 60 mph and the car decides to reboot?!” (Kim Bruno - CFTC)

Will blackouts happen as often as my server goes down? As often as there’s a runaway virus??

Or as often as I get that “Unexplained error has occurred – Eudora will now shut down” ???

It's Gotta be *Really* Reliable: Jack Welch's Six Sigma

(Defects Per Million Operations – DPMO)

Allowed 3.4 DPMO w/ 6σ (5σ is 320 DPMO)

Electricity: one hr. blackout every 33.4 yrs.

New York City – George's Career:

- 42 yrs. – 3 blackouts – '65, '77, '03 – 66 hrs.
- 179 DPMO – between 5 & 6σ

Generation Adequacy:

- 1 day in 10 yrs. = 274 DPMO – close to 5σ

Best system: as fail safe as possible

Smart Grid (cont.)

**The best, most reliable system will be as close to a fail-safe system as possible.
K.I.S.S.**

The more bells and whistles, the greater the possibility of failure.

Cessna vs. F-18.

Proper role of “smart” technology is within future, smaller synchronous interconnections.

6. Properly Structured Markets Will Take Care of *Everything*

When the Laws of Economics and the Laws
of Physics Collide ...
Physics Always Wins!

Kirchhoff's Laws

No economic theory, no legislation, no gov't.
regulation can change the Laws of Physics

Kirchhoff's Revenge

There once was a fellow named Kirchhoff
Whose laws many people steer clear of.
You'd better obey them
Or you'll have just mayhem,
And Kirchhoff will come box your ears off!

© George C. Loehr 1997

Questions?

**PS: see Aug. '04 “Sky & Telescope” magazine
– interesting article on the development of
spectroscopy in astronomy, including the
work of Gustav Kirchhoff and Robert Bunsen**

Other Myths

- 7. The grid is a patchwork of lines built by individual utilities without coordination.
- 8. Not built for long distance transfers.
- 9. It's all because of the growth in electrical demand (a.k.a. load growth).
- 10. Two words: *Vegetation management*.
- 11. “We stopped the spread of the blackout!”

7. Patchwork ... No Coordination

- Power Pools – PJM, NYPP, NEPOOL
- Regional Reliability Councils
- MEN, VEM, VAST, etc.
- Culture of Cooperation & Coordination
- Example: HQ-NE Phase 2
 - Major changes to plan
 - Major changes to operating procedures
 - “Golden Rule”

8. Heavy/Long Distance Transfers

- Going on for decades:
 - Southern / TVA
 - Niagara / St. Lawrence
 - PJM / Minemouth
 - Pacific Northwest to California
 - Four Corners, Intermountain, etc.
 - Quebec to New York, New England
 - MEN / VEM
 - VAST

9. Load Growth

- Electrical demand has grown steadily since Thomas Edison & Pearl St. Station in 1882.
- Through wars, recessions, etc.
- One exception – the Great Depression.
- 1960s: 7 to 7 ½ %
- Now: about 1 ½ %

10. “I Talk to the Trees....”

Is it *really* all about “vegetation management”?

- 1972 upstate NY (near miss)
- 1996 West Coast
- 2004 Midwest/Northeast
- 2004 Italy ----- etc., etc., etc.

“... till Birnam wood to Dunsinane shall come”

Rogue Ents from Tolkien’s *Lord of the Rings*

11. “We Stopped the Spread of the Blackout!”

- System doesn't work that way.
- '50s Sci Fi flick, *The Blob*.
- Instability occurs in seconds.
- Function of system configuration, pre-conditions, Kirchhoff's Laws.
- Kirchhoff's Laws cannot be repealed!
- Will you be part of it or not?
- **Dumb luck !**

Edmund Burke

(18th Century Irish Statesman)

“The age of chivalry is gone.
That of sophisters,
economists, and calculators,
has succeeded.”

Cicero

“O Tempora! O Mores!”

Not Causes of the Blackout

- “Deregulation” hasn’t gone far enough.
- Don’t have the right “market structure.”
- Computer systems were down.
- Operators didn’t notice lines were tripping.
- Poor vegetation management.
- Transmission grid is inadequate (“Third World Grid”).
- Standards (criteria) aren’t “mandatory.”

Real Causes of the Blackout

- Fundamentalist reliance on “markets.”
- Cavalier attitude toward reliability in general, strong criteria in particular.
- “Deregulation” – Physics suborned, forced into econometric mold.
- **Incompetent officials – culpable ignorance.**
- Lack of “military” authority – bad protocols.
- Small control areas, patchwork quilt.

Patchwork Quilt

Types of Super-Entities:

- Regional Reliability Councils
- ISOs / RTOs
- Market Areas
- Control Areas

Defense de Overlap !

Edmund Burke

(18th Century Irish Statesman)

“All that is necessary for the triumph of evil is for good men to do nothing.”

Questions?

“ISLANDS AND BRIDGES”

(John Howe, American Superconducting)

Question: Can we use the Laws of Physics to create a genuine national market?

Break the present Eastern & Western grids into smaller interconnections tied with HVDC

Cost: \$7 – 10 billion (1 mill/kwh for 2 yrs.)
2 yrs., 60 cents/mo. for 600 kwh electric customer

Advantages

DC is asynchronous – what happens *there* doesn't affect *here*.

- Any major disturbance will be contained.
- Simpler, more controllable systems.
- No problem with differing standards/criteria.
- Lower profile for NERC & FERC.
- Minimizes effects of a terrorist attack.
- Maintains local political & technical control.
- **Makes the system work the way the economists *think* it works.**

Cost Comparisons

- 8/10/96 outage in California – approx. \$1 billion
- National outage – approx. \$25 billion/day
- U.S. power failures– approx. \$50 billion/yr.
- One space shuttle – \$2 billion
- Adding one lane to I-81 in Virginia – \$22 billion
- Boston's Central Artery Project – \$11+ billion
- Investment in mass rail transit, 2001 – \$52 billion
- Drop in Bill Gates's net worth, 2001 – \$11 billion
- **Aug. 14, 2003 blackout – \$6 to 10 billion**

Albert Einstein

“Since the mathematicians got
hold of the Theory of
Relatively,
even I don’t understand it.”

Common Objections

- Many small instead of single national mkt.
- Inflow from grid necessary for L/O gen.
- Greater MW line losses
- DC not as inherently stable as AC
- FACTS *si* ... DC *no*
- “Smart” technologies
- How large should the “smaller” grids be?

Bigger than a Breadbox....

How large should the new grids be?

- Too large, lose benefit of smaller grids
Complexity, vulnerability
- Too small, technical problems
Frequency dip for loss of large unit
- Min. – about 20x sum of the 2 largest units
- Between 30,000 & 60,000 MW

The *Real* Problems

- Cost
- Ignorance (culpable or otherwise)
- Cognitive dissonance
- Entrenched interests

- **Coordination**
- **Political will**

Top Excuses For a Blackout

3. **“A tree did it.”** -- July 2, 1996 Western U.S., 2003 Midwest/Northeast, 2003 Italy, etc.
Birnam Wood to Dunsinane
2. **“It was an act of God.”** -- Con Ed CEO following July 13-14, 1977 New York City blackout
1. **“A UFO drained power from an Upstate New York power line.”** -- November 9, 1965 Northeast Blackout

SPECIAL AWARD

Everything you heard on TV Aug. 14-15, 2003.

Smaller Grids / HVDC

References

- “Take My Grid, Please! A Daring Proposal for Electric Transmission,”** by George C. Loehr – *Public Utilities Fortnightly*, May 1, 2001
- www.ameredinst.org./library/loehr.html – click on title
 - Or contact me directly: gloehr@eLucem.com

General HVDC References

- Kimbark (3 volumes) – especially Vol. 1
- Adamson & Hingorani – “HVDC Transmission”

“Till Birnam Wood to Dunsinane Shall Come”

- Macduff's army cuts trees from Birnam Wood to use as camouflage.
- Macduff is a Caesarean birth (not “born” of woman).
- In the end, Lady Macbeth goes mad and Macbeth is killed by Macduff.
- Sometimes things do work out !

Summary

**When the Laws of Economics and the Laws of
Physics Collide ... Physics Wins!**

**“All that is necessary for the triumph of evil is
for good men to do nothing.”**

George C. Loehr
gloehr@eLucem.com

Power Engineers Supporting Truth (PEST)
www.PEST-03.org